Forest Health Protection

Pacific Southwest Region
Northeastern California Shared Service Area

Date: March 17, 2022
File Code: 3420

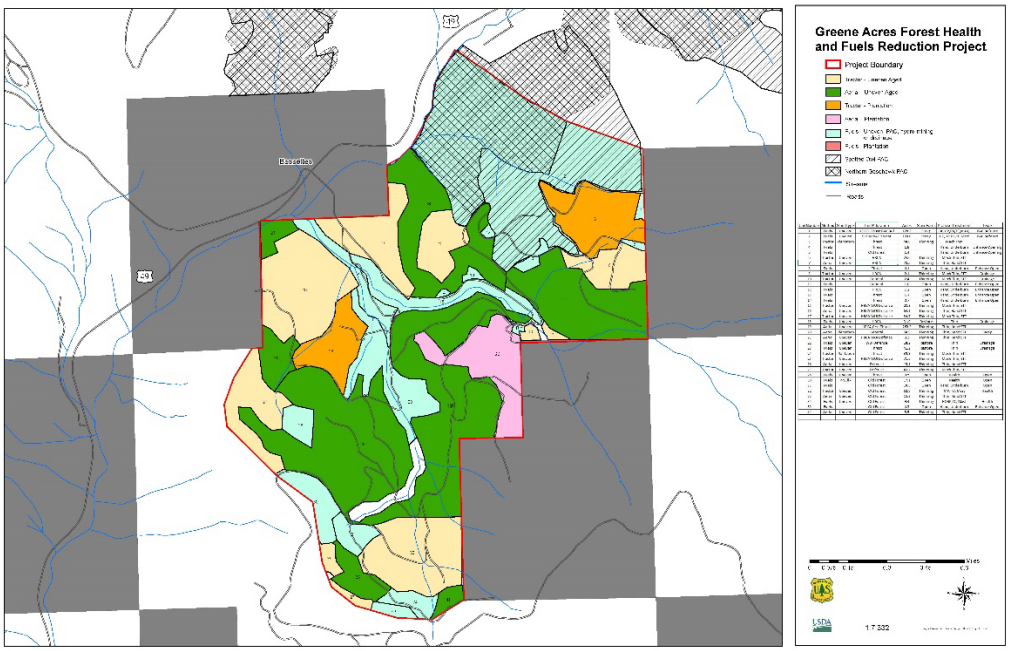
To: District Ranger, Yuba River RD, Tahoe NF

Subject: Managing Heterobasidion Root Disease (HRD) in Greene Acres Project **(Lat 39.608455 Lon -120.577462)** (FHP Report NE 22-02).

On November 29, 2021, Roger Brown (YRRD Silviculturist) and Bill Woodruff (R5 FHP Plant Pathologist) visited several proposed units in the Greene Acres Project (Figures 1&2). The forest is mixed conifer which is now overstocked with diseased white fir at lower elevations and diseased red fir at higher elevations. Heterobasidion root disease (HRD), cause by the fungus *Heterobasidion occidentale,* is infecting white fir and red fir trees throughout Greene Acres Project (Figures 3,4,5,6)

Most of the project area has been logged at least once. Many red fir overstory trees are infected with dwarf mistletoe (DM), (*Arceuthobium abietinum* subsp. *magnificae*). Many white fir overstory trees are also infected with DM (*A. abietinum* subsp. *concoloris*). Dwarf mistletoe in the overstory trees threatens healthy true fir regeneration with infection. If infected overstory trees remain, understory fir trees will continue to be infected and reinfected every fall by DM seed propelled from overstory trees. The result will intensify the current DM/HRD in the Project area (Figures 5, 6).

Figure 1. Green Acres Project Area SE of Bassetts California



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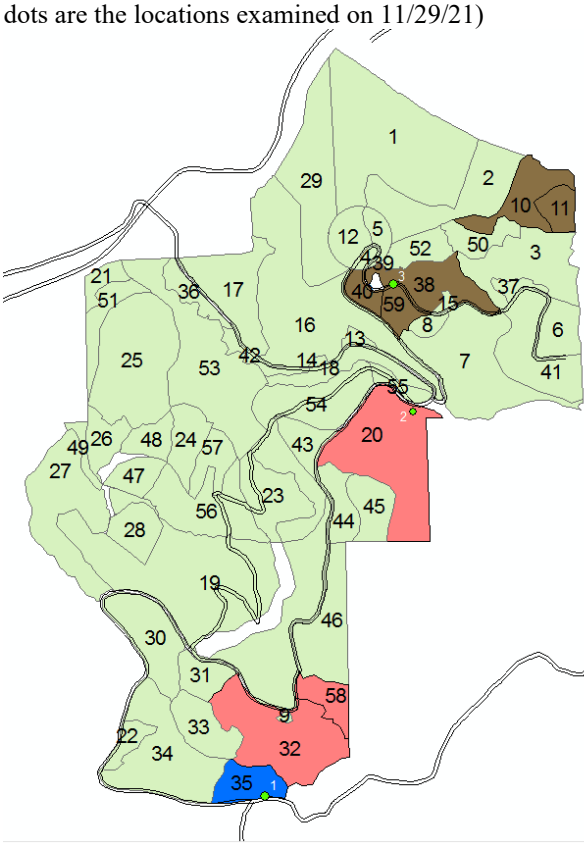
Proposed HRD/DM treatments in the Greene Acres Project are:

1) Control HRD and DM/Cytospora in units 20, 32, 35 and 58 by removing infected overstory and understory red fir trees and plant non-HRD/DM-host pine seedlings where needed. Some units resulted from seed tree prescriptions which left under-stocked red fir regeneration with ever-increasing HRD and DM/Cytospora.
2) Control HRD/DM/Cytospora in units 10, 11, 38, 40 and 59 by removing infected overstory and understory white fir trees and plant non-HRD/DM-host pine seedlings where needed. The units were harvested at least once. HRD probably intensified in the white fir stumps and roots following harvests. DM/Cytospora, where is also intensifying in the overstory and understory.

Note: HRD can be prevented from infecting healthy roots by treating stumps with a borate product registered for preventing HRD (e.g. Cellu-Treat) (see Appendix B). However, since most true fir roots in the project area are already infected with *H. occidentale*, treating true fir stumps would be ineffective. However, pine stumps greater than 14" will benefit from stump treatment.

Figure 2. Greene Acres Project proposed units (blue, red and brown)(White numbers 1,2&3 at the green dots are the locations examined on 11/29/21)



Discussion:

The only way to rid a forest of HRD is to remove all infected host trees for approximately thirty years. Non-HRD-host species can be regenerated during this thirty years. When all HRD root wood has been consumed by *Heterobasidion spp*., the fungus dies. Note: Wildfire can remove disease from forests. Recent wildfires in California have severely burned large acreages of HRD-true fir trees; thus sanitizing those acres of the disease. Likewise, DM and other bole and root diseases have been recently sanitized from large forest acreages by intense wildfire.

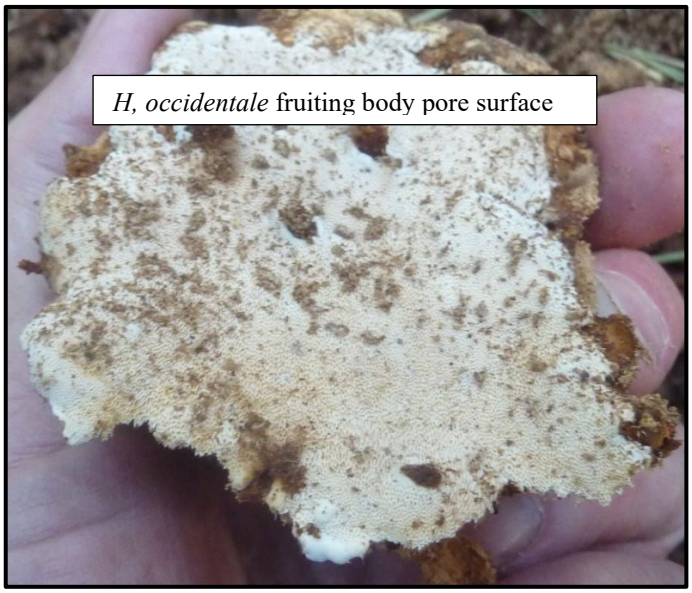
H. occidentale decays mostly heartwood in roots of true fir trees. The cambium of a mature fir tree with HRD is usually not killed by the disease. A true fir tree with HRD can live and grow as long as the tree gets enough sunlight and water. However, because HRD in a true fir tree eventually results in compromised roots, the tree is weakened and the crown starts dying. A true fir tree with little foliage is easily killed by drought, beetles and/or over-stocking; or it dies after falling because its decayed roots can no longer support it.

Emerging DM plants opens branch bark to infection by *Cytospora abietis*, a canker which kills true fir branches and stresses the tree. DM in understory true fir trees typically intesifies slowly. This likely happens because the dense foliage on young trees intercepts most flying DM seed. Therefore DM in young true fir is mostly confined to infected seedlings. Old true fir trees have less foliage in branches to intercept flying DM seed. Therefore DM seed is easily dispersed onto understory trees. DM-infected overstory true fir is a threat to healthy understory crop trees.

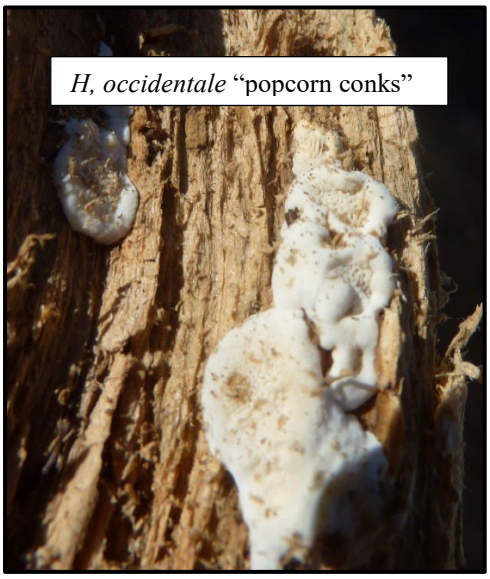
Figure 3. Heterobasidion root disease (HRD) *H, occidentale* decay & fruiting bodies (conks) in white fir

White fir stump with HRD decay

Conk in decaying stump



H, occidentale fruiting body pore surface



H, occidentale "popcorn conks"

Figure 4. Past harvesting of white fir left many stumps & roots infected with *H. occidentale*

Figure 5 shows HRD red fir declining (C,D), slow growing (A,B,E,F,G), dead (A,B,E) and/or with cytospora/DM infected dead branches (A,D,F,G).

Figure 5. Red fir with HRD and DM/Cytospora

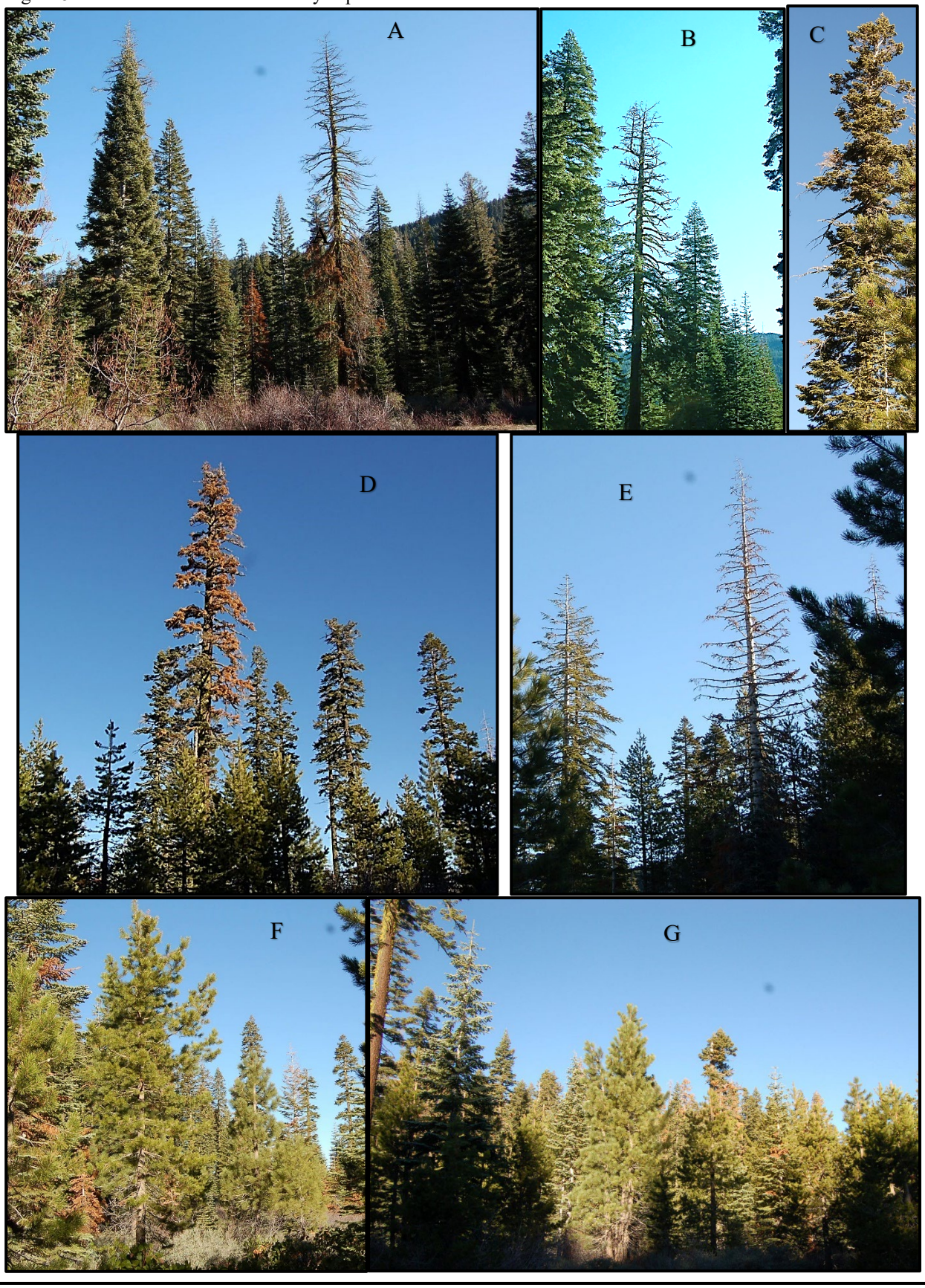
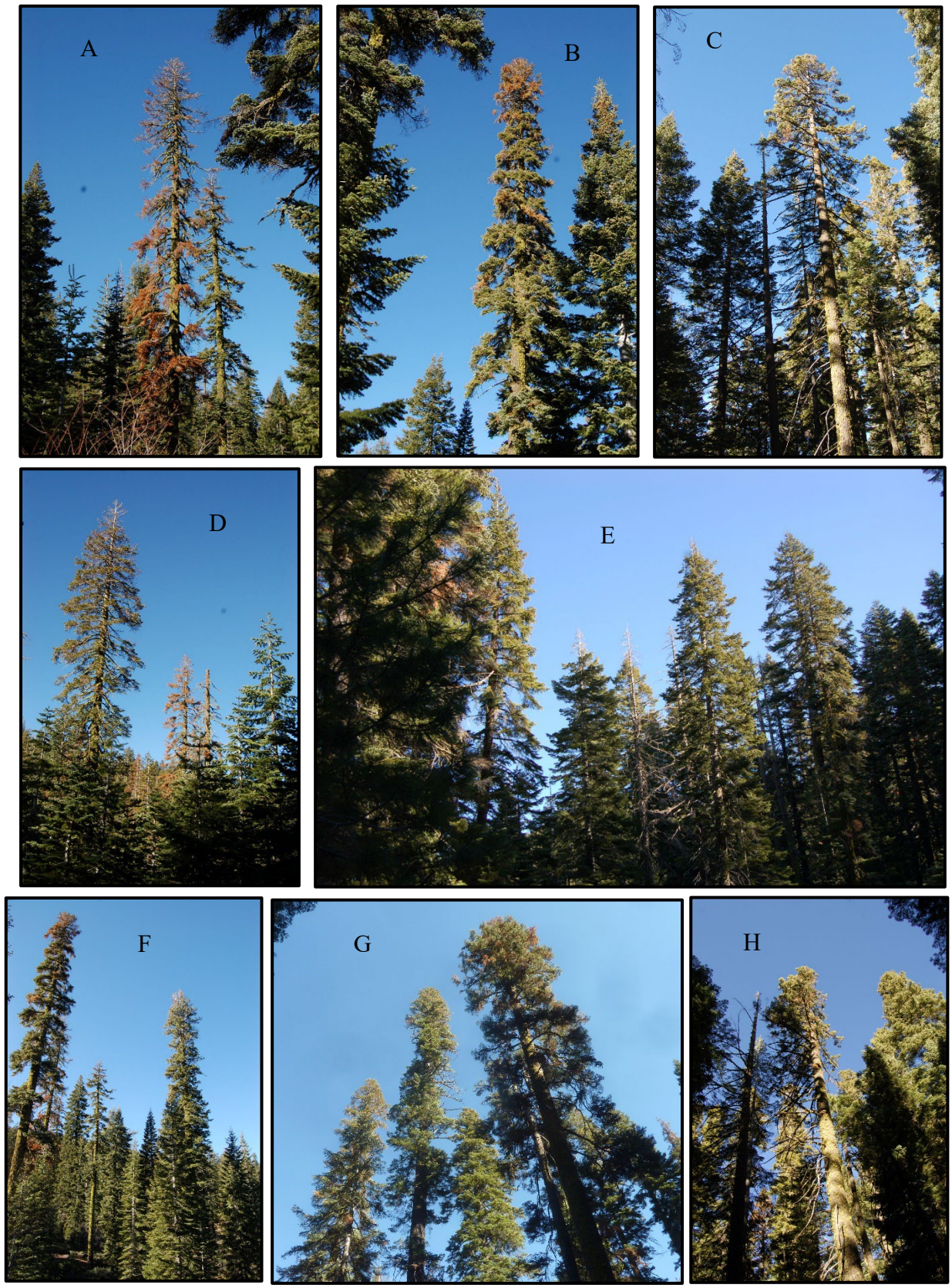


Figure 6 shows HRD white fir declining (B,C,D,F,H), slow growing (C,E), dead (A,C,D,H) and/or with dead cytospora/DM infected branches (A,B,C,D,F,G).

Figure 6. White fir with HRD and DM/Cytospora



The Greene Acres Project area is a forest stressed by HRD and DM. These diseases will not quickly kill lots of trees in large areas like beetles often do. Instead, these diseases reduce board foot growth, limit tree longevity and add dead fuels to the landscape (Figures 7,8). HRD can quickly kill true fir seedlings and saplings (Figure 9). Older true fir are usually killed slowly by HRD & DM/Cytospora (Figure 6: A,C,D,E,H). Often death of HRD and DM/Cytospora stressed true fir trees is accelerated by beetle attacks, primarily *Scolytus ventralis*, fir engraver beetles (Figure 7).

Figure 7. White fir bole with fir engraver galleries

Figure 8. White fir deadfall due to HRD

Figure 9. Red fir saplings killed by HRD

HRD and DM and other tree diseases in the Greene Acres project area are native to California forests. These ever-intensifying diseases can be controlled by:

1) in small stands: harvesting diseased trees and regenerating with non-host trees; or
2) at the landscape level: wildfire; or seed tree harvest enough large HRD/DM areas to fireproof the landscape (see Appendix C)

Effective treatments, from a forest pathology perspective, are the two proposed treatments listed on page 2; only on a much larger scale. Treating and regenerating small stands can control HRD and DM/Cytospora in those stands; but it will do nothing to stop a large wildfire from scorching the landscape and destroying the treated stands in the process.

Traditionally, silviculturists managed the largest number of trees on a landscape possible without incurring significant mortality. Predicted soil moisture and mortality risk helped foresters determine how many trees per acre; how much basal area; and/or what stand density index to manage. However, with today's drying climate and frequent droughts, traditional forestry is not wise; a wildfire today can burn a million forest acres or more. Landscapes need to be made more "fireproof" by creating more open forests (Figure 10 and Appendix C)

Figure 10. Open USFS stand, less likely to burn by crown fire

Large wildfires are not all bad. Before logging in the West, fire was nature's way of keeping forests healthy. When today's wildfires intensely burn a forest, disease is usually eliminated. Unfortunately, severely burned forests take centuries to replace; and unchecked wildfire destroys communities and infrastructure. To keep wildfires from blackening millions of acres, foresters must create continuous landscapes of fireproof forests. The proposed Greene Acres Project will reduce disease on the treated acres; but the treated acres are at risk of being overrun by wildfire as long as the surrounding forest landscape is overstocked with trees and loaded with fuels.

Summary:

The planned treatments in the Greene Acres Project will control HRD and DM/Cytospora on the treated acres. Future treatments need to "fireproof" the dense forests (Figure 11) in the green polygons (Figure 2) surrounding the treated polygons, before wildfire overruns the project area.

For more information, please contact Bill Woodruff at 530-249-7990.

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Figure 11. Overstocked white fir.

Appendix A: Pest Biologies

Heterobasidion root disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species aresusceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has beenreported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in US Forest Service Region 5, California. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, theloss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdlesand kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* and *H. irregulare*. These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* is pathogenicon ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* is pathogenic on true fir, spruce, and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine andtrue fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from theirhosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equaled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow green to orange mistletoe plants, basal cups on a branch or stem wherethe plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

Fir engraver beetle

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Treesgreater than 4” in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced byold spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack (continued: Fir engraver beetle)
Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs.

Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attackpine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain, and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the firflatheaded borer.

Life Stages and Development
In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery.The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in thelarval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its lifecycle in 1 year; however, at higher elevations 2 years may be required.

Conditions Affecting Outbreaks
Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks willoccur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher- than-normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Appendix B.

Borate stump treatment recommendations to prevent Heterobasidion root disease

Priorities for stump borate treatments to prevent Heterobasidion Root Disease (HRD) v.4.5
Contact your Forest Health Protection Entomologist or Plant Pathologist for assistance

USFS Region 5 - BORATE STUMP TREATMENT PRIORITY BY FOREST CONDITION and HARVEST ACTIVITY			
Priority	**HARVEST ACTIVITY in FOREST TYPE and CONDITION**	***TREAT WHICH STUMPS?**	**WHY**
Very Low	Salvage high severity burn (nearly all trees killed); plant	NONE	Little connectivity with seedling roots; Most dead roots get infected with competing organisms before seedling roots contact them
Very Low	Clearcut PP/JP, true fir or mixed conifer; any location including roadsides and powerline corridors	NONE	Very low probability of new establishing new infection centers
Very Low	Thin true fir which has widespread light to heavy HRD	NONE	Borates do not cure existing infection
Low	Thin PP/JP with no current or historic pine HRD within 1700 feet	NONE	Very low atmospheric spore concentration
Low	Thin PP/JP in mixed species stands; few >14" PP/JP stumps	NONE	Small pine stumps don't create HRD centers; small roots get infected fast with competing organisms
Low	Thin PP/JP in mixed species stands; few pine-to-pine root contacts	NONE	HRD won't spread from stumps that don't have root contact w/ live trees
Low	Thin Doug-fir; incense cedar; sugar pine; other conifers	NONE	Little evidence of HRD problems
Moderate	Salvage low to moderate severity burn (scattered remaining green trees)*	Consider treating >14" PP/JP and > 24" juniper stumps having possible root contact with high-value PP/JP. Treat true fir stumps in stands with no fir HRD	Borates do not cure existing infections. Treating pine stumps near high-value pine trees can protect residual pine from HRD. Large juniper stumps may facilitate spread to adjacent pines.
High	Any cutting, PP/JP, true fir in roadside and powerline corridors (including hazard tree removal and salvage* in low to moderate severity burns)	Treat all PP/JP and > 24" juniper stumps and true fir stumps >14"	Borates prevent infection; lower tolerance for new HRD centers in these areas. Large juniper stumps may facilitate spread to adjacent pines.
High	Thin PP/JP in mixed species stands; many >14" PP/JP stumps and pine-to-pine root contacts; pine HRD within 1700 feet (or distance to nearest HRD not known)	>14" PP/JP stumps (also >24" juniper stumps if present)	Borates prevent infection. Large juniper stumps may facilitate spread to adjacent pines.
High	Thin true fir with no HRD	> 14" fir stumps	Borates prevent infection
Very High	Thin PP/JP; many >14" stumps; pine HRD within 1700 feet (or distance to nearest HRD not known)	>14" PP/JP stumps	Every stump can start HRD centers
Very High	Recreation and Administrative Sites	>3" conifer stumps	Zero tolerance for new HRD centers in these areas means treating smaller stumps of all conifer species
Very High	Thin giant Sequoia groves; treat conifer stumps within 1700 feet of monarch giant sequoia trees	>3" conifer stumps	Zero tolerance for new HRD centers in these areas means treating smaller stumps of all conifer species

* No need to treat stumps of trees with no needles or stumps of trees killed by fire >18 months earlier

Appendix C.

Example of a private forest protected from HRD/DM, fire and beetles

A recently harvested 280 acres of private forest adjacent to the Warner Mountain Ranger District, Modoc NF, is located east of the West Warner Road near Brooks Mill (Figures a,b,c), 280 acres of which was recently logged (Lat 41.283138 Lon -120.310633). Most juniper trees were removed, and the pine was aggressively thinned. The result resembles a seed tree prescription. The managers of this private forest were criticized for this type of harvest. However, managing forests of widely-spaced pine trees has at least seven benefits:

Figure a. 280 acre private forest (from Google Earth)

#1) From a forest disease perspective, HRD caused by *H. irregulare* will not be a problem for decades in this 280 acres because there are almost no pine-to-pine root contacts remaining through which the Heterobasidion fungus can spread. However, if stumps were not treated with a borate fungicide, the logging may have left a few large HRD infected pine stumps which may spread the disease to nearby pine trees. However, any pine tree that gets HRD from infected stumps will not spread HRD to other pines without root connections. Likewise black stain root disease (BSRD), caused by the fungus *Leptographium wageneri* will not be a problem. BSRD has not been reported in the Warner Mountains; but nearby Devils Garden RD, north of Crowder Flat, has a history of BSRD as well as HRD.

Figure b. Private forest resembling a seed tree prescription.

#2) The Brooks Mill harvest area (Figures a, b & c) will have no new Western Dwarf Mistletoe (*Arceuthobium campylopodum*) problems for decades. The disease will intensify in pine trees that are currently infected; but no catapulted sticky dwarf mistletoe seed, which cannot be effectively shot more than approximately sixty feet, is likely to reach another pine tree; except for any pine seedlings growing near infected trees. Therefore tree-to-tree spread of the dwarf mistletoe has been virtually eliminated from this harvest area.

#3) A huge advantage of the seed tree-like-harvest is that it will be safe from wildfire for decades. Furthermore, if this area is underburned regularly, wildfire should never be a problem. The millions of forest acres that burned with high intensity fire in California in 2020 and 2021 would not have been devastated by wildfire had they been similarly populated with trees.

#4) Less snow and rain will be intercepted by foliage and prevented, by evaporation, from reaching the forest floor where it is needed to grow trees.

Figure c. Part of the 280 acre private forest at Brooks Mill

#5) Drought-caused tree mortality should be minimal in the Brooks Mill harvest area. Pine trees on this 280 acres should have enough water to keep them healthy; even during a severe drought.

#6) Natural regeneration of pine seedlings is usually successful on mineral soil that is exposed to lots of sunlight. The 280 acres will likely have pine regeneration in need of thinning in 2 decades.

#7) Natural pine regeneration that results on the 280 acres should carry the genes natural to the site. The original genetic diversity of the pines on this site will be preserved better than with artificial regeneration using seedlings grown from seed collected from selected pine trees grown elsewhere.

NOTE: Some of the above benefits could have been accomplished by leaving two or three times the number of pine trees standing especially in the stand in Figure c. However, a denser stand would be more likely to carry a crown fire driven by strong winds; and be more susceptible to drought-caused mortality. Also, closer trees would better support the spread of root diseases and dwarf mistletoe.